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GIS-BASED FOR LAND EVALUATION IN SOME AREAS AT WEST OF NILE DELTA

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ABSTRACT: Land suitability evaluation is one of the most effective methods for favorable agricultural land use planning and evaluating the suitability of land for a specific crop. The purpose of the current study is to use GIS and Automated Land Evaluation System (ALES) to evaluate the land capability and crop suitability for various soils and biophysical conditions. The current study was carried out to demonstrate the usefulness of GIS technologies coupled with soil data to evaluate crop suitability for obtaining sustainable cropping systems in the studied area. As input, the model requires soil data for an assessment of the study area, 16 representative soil profiles were used to collect soil samples from different layers depth. The capability evaluation gives four capability orders for agricultural and reclamation land capability, (Class I, good; Class II, moderate, Class III, weak and Class IV, marginal). Moreover, the evaluation model gives four limiting factors suborders, which are topography (t), soils (l), erosion risks (r), and bioclimatic deficiency (b). The suitability of selected field crops indicated that, wheat varied from highly suitable to permanent not suitable in different study areas. Suitability of maize is similar to wheat crop. Selected vegetable crops, tomato and onion are ranged from highly to permanent not suitable. Land suitability of selected fruits, Apple is suitable for marginally suitability for cultivation in different development areas. On the other hand, fig and olive is highly suitable for the most of the area.

Key words: GIS, Land evaluation, ALES program.

INTRODUCTION

Land evaluation is an approach applied to evaluate land suitability for a specific use. Land evaluation is a knowledge-based and requires an extensive data base and different conditions to be fulfilled. This can be done automatically by the use of ALES, LECS and GIS systems (**Ganzorig, 1995**).

Land capability evaluation refers to a range of major kinds of land uses, such as agriculture, forestry, livestock production, and recreation. The most widely used categorical systems for evaluating agricultural land is termedland capability classification (**Sys *et al.,* 1991**). Land capability classification provides a guide for the assessment of soil constraints and land management recommendations for use at a range of scales including state, catchment and the property planning level (**Murphy *et al.,* 2004**).

El-Sebery (2016) used MicroLEIS-Cervatana module for capability assessment of some areas in middle Egypt, and found that 19.20% of land was very good with none limitations, while 31.70% land was good capability with main limitations being soil properties and erosion risks and 40.95 % land was moderately with main limitations regnding to soil properties, erosion risks and bioclimatic deficiency.

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Nevertheless, **Hassan (2017)** used MicroLEIS-Cervatana module for capability assessment of some areas in middle Egypt and found that 8.50% of land was good with main limitations is being erosion risks, 24.72% of total area was moderate capability with main limitations being erosion risks and bioclimatic deficiency and 9.14% of total area was marginal or null with main limitations being slope and bioclimatic deficiency.

Suitability considers the environmental variables such as topography, soil, vegetation and landforms. However, the integration of these various variables in a single assessment gives accurate and efficient results when GIS is used (**Steiner *et al.,* 2000 ; Zhang *et al.,* 2011**).

Land suitability is defined as the fitness of a given type of land for a specified land use type. This can be based on economic and physical metrics. An economic definition of suitability can be based on defined metrics of economic value, *e.g.*, predicted gross margin, net present value, internal rate of return, benefit cost/ratio. A definition of land suitability is more arbitrary, being based on a specified method for combining land quality ratings into an overall rating. The idea is to give the land user a feel for how limiting, or how difficult to manage, the land is for the proposed land use type (**Rossiter, 2001**).

Land resources won't overcome the needs of such population. So, there is an urgent need to mach land type and uses, in the most practicable and logical ways, to achieve sustainable production, and to meet the needs of society conserving ecosystems (**Abd El-Kawy *et al.*, 2010**).

Land evaluation and crop suitability analysis would resolve these issues while providing better land-use options to the farmers. It is known that continued practice of one cropping system type would resulted in deteriorating soil health and reduce soil resilience for maintaining productivity by evolving soil allopathic or growth of deleterious microorganisms in the soil. This causes a yield decline, which cannot be improved with the application of mineral fertilizers (**Oz and Friedman, 2001**).

Analysis of crop suitability under various systems that could be grown in a given area is essential. Remote sensing (RS) data are used for estimating biophysical parameters and indices besides cropping systems analysis, and land-use and land-cover estimations during different seasons (**Rao *et al.,* 1996 ; Panigrahy *et al.,* 2006**).

Geographic information systems are powerful tools for data handling, processing and management and solving environmental problems, however such tools can do nothing without field measurements and standard methods (**Panigrahy *et al.,* 2006**).

El Baroudy (2016) employed a spatial model for land suitability assessment for wheat crop integrated with geographic information system (GIS) techniques in the northern part of the Nile Delta. Organic matter, N, P, K, Zn, drainage, texture, depth, topography, surface stoniness, hard pan, hydraulic conductivity, water holding capacity, salinity, ESP, $CaCO_3$ and pH were recognized as factors affecting land suitability for wheat crop in the study area. Three thematic indicators were used in assessing land suitability, soil fertility, chemical and physical properties quality indices.

Land capability and suitability maps are confirmed with the mapping units on the physiographic map for producing the productivity map due to the Agriculture Land Evaluation System, ALES for arid and semi arid regions, has been adapted by (**Ismail *et al.,* 2001**) to estimate the agriculture land evaluation. ALES-arid is linked directly to its relational database and coupled indirectly with a GIS through the loosely coupled strategy.

Therefore, the objectives of this study are to investigate the land evaluation by using the GIS, and to assess the potentiality of selecting the best agricultural land use for a particular reclaimable area based on soil quality and water irrigation quality.

MATERIALS AND METHODS

Location of Study Area

The investigated area is lying at west of Nile Delta and located between longitudes 29º 27` 30`` and 29º 52` 0`` east, and latitudes 30º 45` 00`` and 30º 57` 30`` North as shown in Fig. 1.

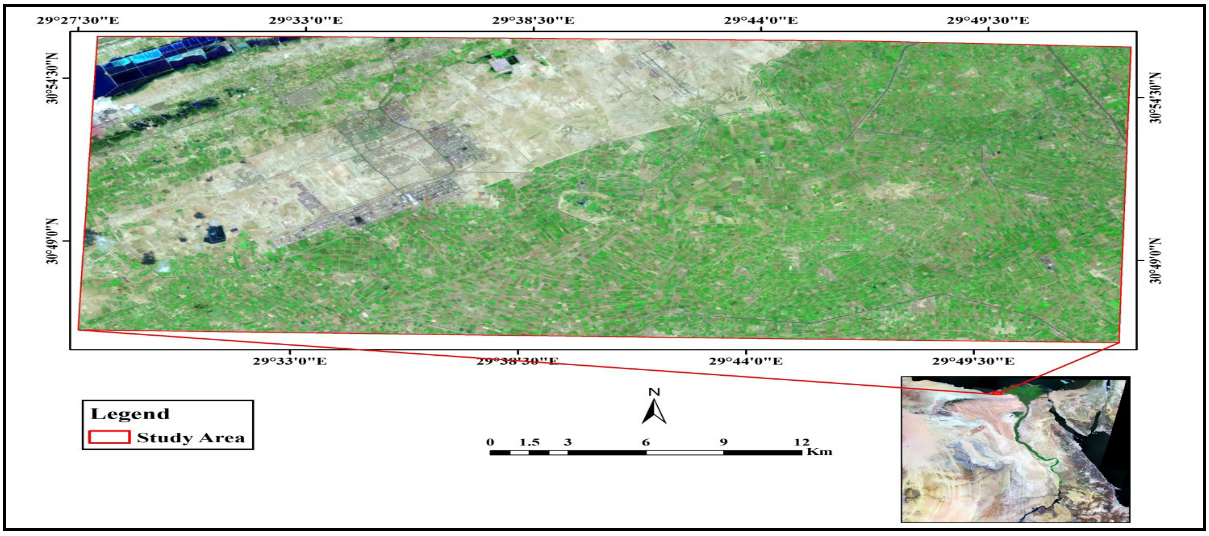

Fig. 1. Location of the study area

The territory is climatically characterized as a rainy winter and a hot and dry summer as Mediterranean climate. The amount of annual precipitation in winter between October and March ranged from 150 to 200 mm/year. The maximum monthly temperature is 33ºC in July, the minimum temperature is 9.5ºC in January, and the mean annual temperature is 25ºC.

The geomorphologic map of the investigated area is produced based on integration of topographic elements slope, aspect, curvature and relief intensity and remote sensing data.

Fieldwork and Laboratory Analyses

Sixteen representative soil profiles were chosen according to the variations of color of the corrected Landsat image to verify their soil characteristics. Soil profiles were morphologically described according to the soil morphological map. Disturbed, undisturbed and composted soil samples were collected. The soil samples were collected and dried, sieved and stored in a polyethylene container to be ready for soil characteristic determination as well as physical, chemical and fertility properties. Irrigation, drainage water and water table samples were collected from soil profiles. Laboratory analyses (*i.e.* Soil texture, $CaCO_3$ content, CEC, EC, ESP, pH, soluble cations and anions, organic matter content and available N, P, K) were carried out using the soil survey laboratory methods manual (**USDA, 2004**).

Land Capability Modeling

A land capability modeling procedure was applied, following the generally accepted ALES capability. The ALES capability model works interactively to compare the values of the land-unit characteristics to be evaluated with the generalization levels established for each capability class. Following the general accepted of land evaluation (**FAO, 1976**), the ALES capability model forecasts the general land use capability for a broad series of possible agricultural uses. The methodological criteria refer to the system designed earlier by (**Ismail *et al.,* 2001**).

Prediction of general land use capability is the result of a qualitative evaluation process or overall interpretation of the following biophysical factors: relief, soil, climate, and current use or vegetation. For each diagnostic criterion or limiting factors, the land characteristics were selected, and the corresponding levels of generalization were established and related with the capability classes by means of gradation matrices. The procedure of maximum limitation was used with matrices of degree to relate the land characteristics directly with capability classes. Matching tables were used and linked to the GIS modeling environment using relational database fields which have identified key attribute property.

A land capability evaluation of soils in the studied area was performed, using ALES land capability model. The capability classification procedure was done through matching soil characteristics and qualities with capability limiting factors using the maximum limiting factor method. The capability evaluation includes four capability orders for agriculture and reclamation land capability which are excellent (C1), good (C2), moderate (C3) and marginal (N) or C4. Also, the evaluation model includes four limiting factors suborders which are topography (t), soils (l), erosion risks (r), and bioclimatic deficiency (b).

Land Suitability Modeling

Land suitability evaluation, modeling was applied following the well-known ALES suitability model (**Ismail *et al.,* 2001**). The ALES suitability model is a physical soil suitability evaluation model indicates the degree of suitability for a land use, without respect to economic conditions.

The land use requirements were matched to the land characteristics of each mapping unit to determine its suitability depending on the gradations considered for selected criteria (gradation matrices) and on the different agricultural uses. The suitability classes for each crop are: soils with optimum suitability (S1), soils with high suitability (S2), soils with moderate suitability (S3), soils with marginal suitability (S4), and soils with no suitability (S5). The main soil limitations are: useful depth (p), texture (t), drainage condition (d), carbonate content (c), salinity (s), sodium saturation (a) and degree of development of the profile (g). For each diagnostic criterion or limiting factor, the land characteristics were selected, and the corresponding levels of generalization were established and related with the suitability classes by means of gradation matrices. In the suitability model, the evaluation results are presented in the form of a matrix, that is, a two dimensional array with rows, including the soil characteristics and columns consisting of the soil units for which the evaluation was computed. The intersection of the two (*i.e.* the cells of the matrix) are considered as the result. The overall soil suitability of a soil component (unit) was assessed through the maximum limitation, method where the suitability is taken from the most limiting factor of soil characteristics.

Maps Production

Image processed, surface units, geomorphologic, soils, land capability, land suitability, and agricultural priority maps were layout, annotated, projected and finally produced using Arc GIS software.

RESULTS AND DISCUSSION

Geomorphologic Map of the Study Area

Geomorphic units were identified throughout interpreting satellite image as well as digital elevation model of the study area. The geomorphic units were recognized and delineated by analyzing the main landscape with the aid of the different maps and field survey. The obtained results showed that, the study area is including the following units; sand plain, inter ridge depression, high over flow basin, decantation basin, low over flow basin, over flow basin, table land, ridge, inter ridge slope as show in Fig. 2.

Land Capability

The outputs of the model were linked, to the GIS modeling environment using relational database fields which have identified key attribute property through matching tables to obtain the final maps for land capability in the studied areas (Fig. 3). The results of the capability model revealed the following:

a- Lands of capability order (C1) were not included in the entire studied soils in all developmental areas.

b- Lands of capability order (C2) include some soils of the study areas. These lands present a good capability and can be managed with little difficulty. The main limitations of these lands with C2 capability class are soils, erosion risks, and bioclimatic deficiency. These lands require good and proper management. Under good management, they are moderately high to high in productivity for a fair range of crops.

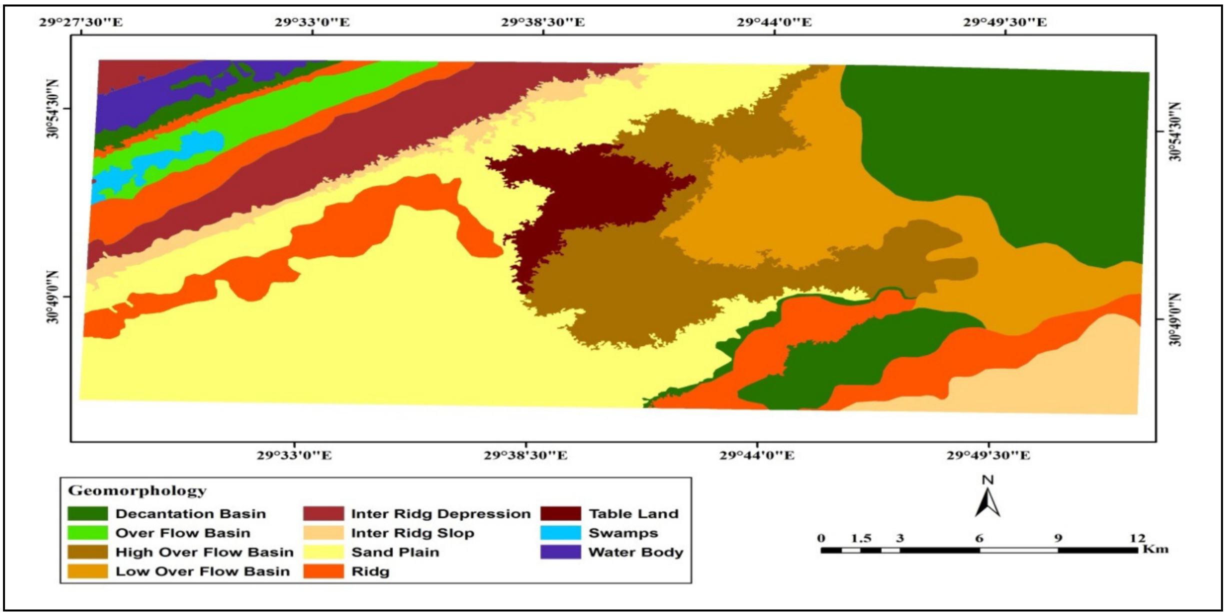

Fig. 2. Geomorphological units of the study area

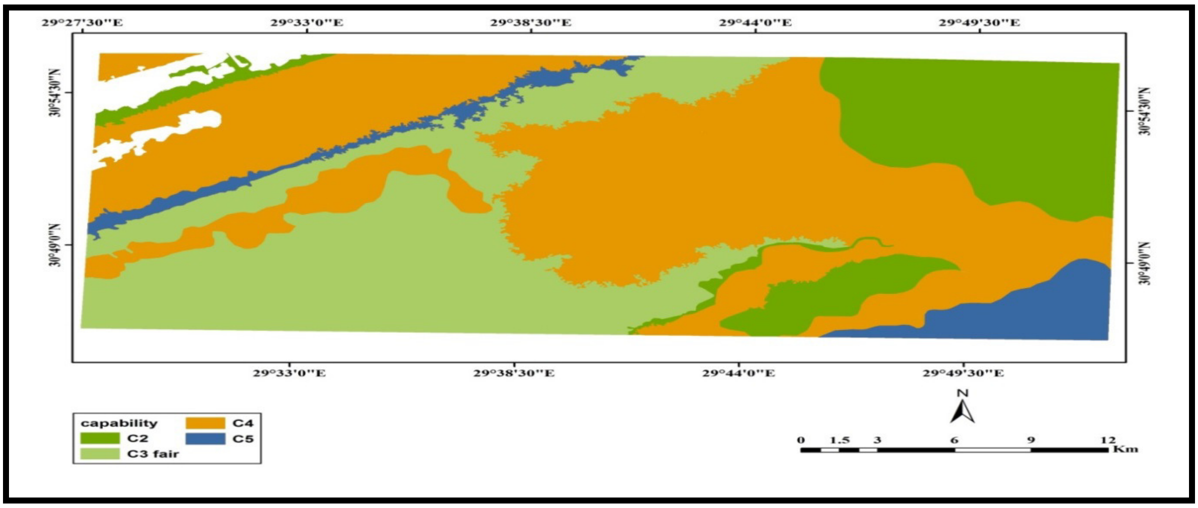

Fig. 3. Land capability map of the study area

c- Lands of capability order (C3) include the entire soil types of the study areas. These lands have moderate capability and moderately severe limitations that restrict the range of crops and require special conservation practices. The main limitations of these lands differed from soil, erosion risks, and bioclimatic deficiency. Similar lands have low to fair productivity for fair range of crops and improvement practices can be feasible.

d- Lands of capability orders (C4 and C5):

A land of capability orders (C4 and C5) includes different areas. These lands have of marginal capability and very severe limitations that restricts their use for arable culture. The main limitations of these lands with C4 and C5 capability classes are soil depth, texture and ECe and bioclimatic deficiency. These lands have low to marginal productivity and recommended for producing forage crops, forestry and agroforestry systems. The percentage of each class is shown in Table 1 and Fig. 3.

Table 1. Land capability of the studied area

Land capability	Occupied area (%)	Occupied area (fad.)	Occupied area (ha)
C1	0.00	0.00	0.00
C2	17	30254	12706
C3	1	2118	890
C4	52	90746	38113
C5	25	51691	21710
Swamps	0.3	483	203
Water bodies	0.74	4453	1870
Total	100	179745	75492

Land Suitability

The ALES Land Suitability model used a Decision Support System (DSS) to stand on the main factor(s) that govern the soil suitability and productivity. The ALES Land Suitability model is based on crop suitability that affected by potentiality of the environment (*i.e.* the dominant soil characteristics). The overall soil suitability of a soil component (unit) was assessed through the maximum limitation method. The suitability is taken from the most limiting factor of soil characteristics. Eleven traditional crops are considered as follows: wheat, barely, maize, alfalfa, date palm, fig, olive, watermelon, apple, tomato, and onion. These crops were selected to be evaluated on the available soil conditions of the study area under investigation. The outputs of the model were linked, to the GIS modeling environment using relational database fields which have identified key attribute property through matching tables to obtain the final maps for land suitability classes of study areas. Figures 4, 5, 6, 7, 8, 9 and 10 were selected to show the spatial distributions for suitability of some selected crops.

The result indicates that only 33.7% of agricultural land can be demarcated as highly suitable for maize, alfalfa and onion cultivation whereas 66.6% of agricultural land as suitable for olive cultivation in the study area. These lands are utilized for multiple purposes. They are mainly used for agricultural, pastures and orchards. Depending on the nature and properties of soils, they are suitable for one or other uses.

Aspect of land suitability for the crops and orchards were determined based on climate, soil and topographic variables. The study area was delineated according to suitability classes for wheat, maize, fig, apple, tomato and onion growing on the studied area as shown in Table 2.

Maize, alfalfa, and onion are the major crops cultivated in the area. Spatial analysis shows that nearly 33.7% of the total area is highly suitable for there.

However, 46.2% of the area is moderately suitable. Gravel and soil texture are the main factors for decreasing the suitability. This indicates that more area can be brought under cultivation with improvement of soil conservation and management practices. For wheat, date palm, fig , olive and tomato 27.7%, 29%, 17%, 27.7% and 17.04%, respectively of the area were found to be highly suitable employed in their best uses, Likewise, there is unsuitable (NS) class for all the crops as shown in Table 3.

Conclusion

Application of GIS and ALES software for land evaluation targeting land use planning and decision making in sustainable agriculture has been reached significant results and effective tools.

The set of maps, especially recommended land suitability map, of agriculture expansion in some areas at west of Nile Delta is a very helpful database not only for decision-makers, but also farmers to decide what kinds of crops should be used avoiding competition between themselves.

Table 2. Land suitability classification for selected crops

Profile No.	Wheat suitability (Degree)	Wheat Suitability (Rate)	Maize suitability (Degree)	Maize suitability (Rate)	Tomato suitability (Degree)	Tomato suitability (Rate)	Onion suitability (Degree)	Onion suitability (Rate)	Fig suitability (Degree)	Fig suitability (Rate)	Apple suitability (Degree)	Apple suitability (Rate)
1	S1	86.29	S2	67.68	S1	72.54	S2	70.9	S4	27.8	S4	22.2
2	S2	70.58	S3	47.02	Ns1	18.32	Ns1	13.9	S3	45.8	S2	66.6
3	S1	80.54	S2	60.52	S2	71.7	S2	62.99	S4	22.14	S4	33.5
4	S3	67.98	S3	53.78	Ns1	13.28	Ns1	10.39	S1	82.49	S3	45.8
5	S2	73.05	S2	72.03	S1	88.68	S3	40.3	S2	73.09	Ns1	18.92
6	S3	48.87	S4	22.5	S2	77.89	S2	68.87	S2	74.3	S2	68.84
7	S2	41.6	S3	47.64	Ns1	18.5	Ns1	11.3	S1	83.21	S3	56.7
8	S2	63.36	S3	54.98	Ns1	17.9	Ns1	15.5	S1	89.63	S3	54.9
9	S2	65.58	S3	57.61	Ns1	11.9	S3	47.9	S1	82.6	S2	73.8
10	S2	64.47	S4	35.87	S2	65.3	S1	90.5	S2	70.1	S3	12.65
11	S1	82.33	S3	48.78	S2	76.8	S3	54.2	S2	71.5	S3	15.7
12	S2	64.64	S1	82.5	S2	60.89	S2	68.87	S2	76.98	S2	62.24
13	S2	62.17	S2	61.13	S1	88.2	S3	42.9	S2	78.01	Ns1	18.65
14	S2	62.67	S4	25.67	S2	70.43	S1	84.8	S2	65.89	S3	44.4
15	S2	65.14	S4	39.8	S2	67.8	S1	81.9	S2	77.8	S3	55.8
16	S2	62.43	S3	55.67	Ns1	15.6	S3	45.9	S1	84.18	S2	64.59

S1 (highly suitable), S2 (suitable), S3(Moderately suitable), S4(marginally suitability), NS1 (currently non suitable).

Table 3. Land suitability classification for selected crops

Land suitability classes	Crops and fruits (% of the total area)										
	Wheat	**Barely**	**Maize**	**Alfalfa**	**Date palm**	**Fig**	**Olive**	**Watermelon**	**Apple**	**Tomato**	**Onion**
S1	27.7	0	33.7	33.7	29	17	27.7	0	0	17.04	33.7
S2	38.2	51.1	29.2	2.5	25	48.9	66.6	34.2	53.8	48.9	28.3
S3	31.4	46.2	3.4	25.8	3	28.4	0	31.7	12.1	0.03	4
S4	0	0	31	35.3	37.3	3	0	0	29.1	31.33	31.4
NS	0	0	0	0	3	0	3	31.4	2.3	0	0
Reference terms	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7

Note: Reference terms refer to the water body and swamps.

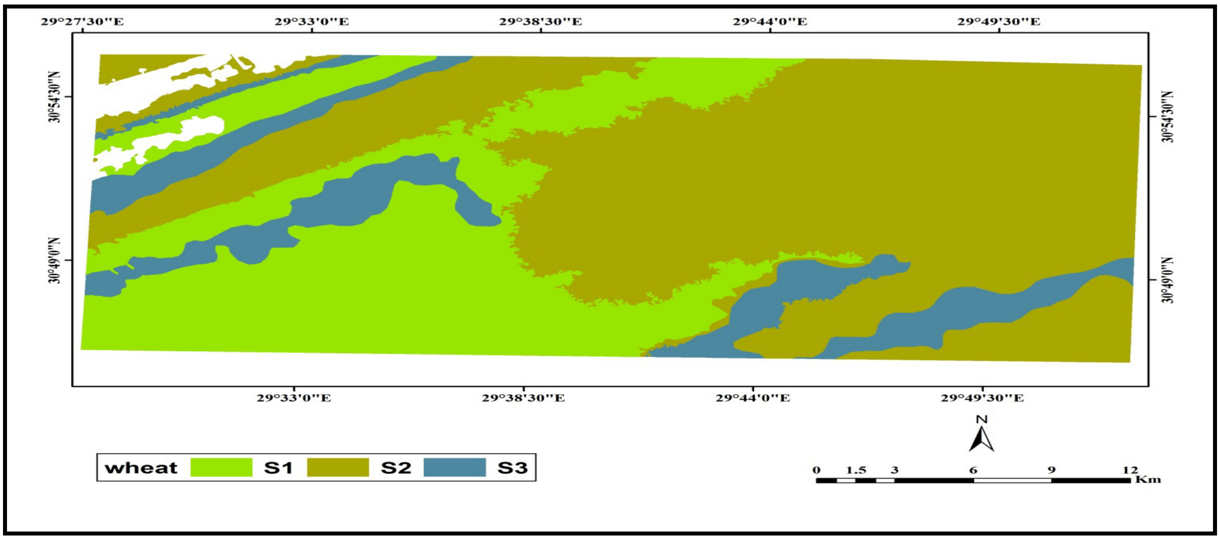

Fig. 4. Land suitability map for Wheat

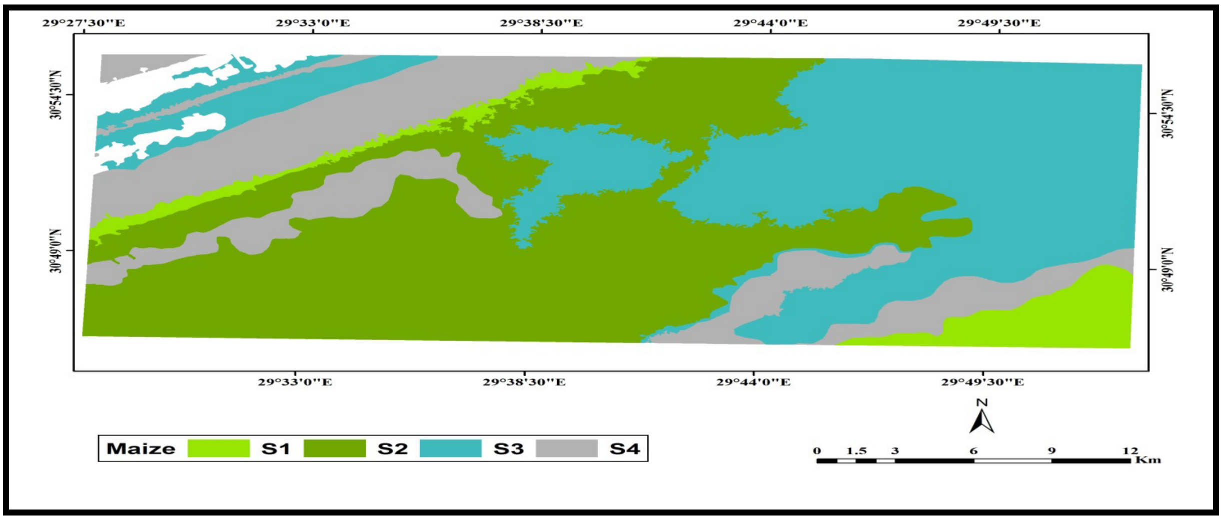

Fig. 5. Land suitability map for Maize

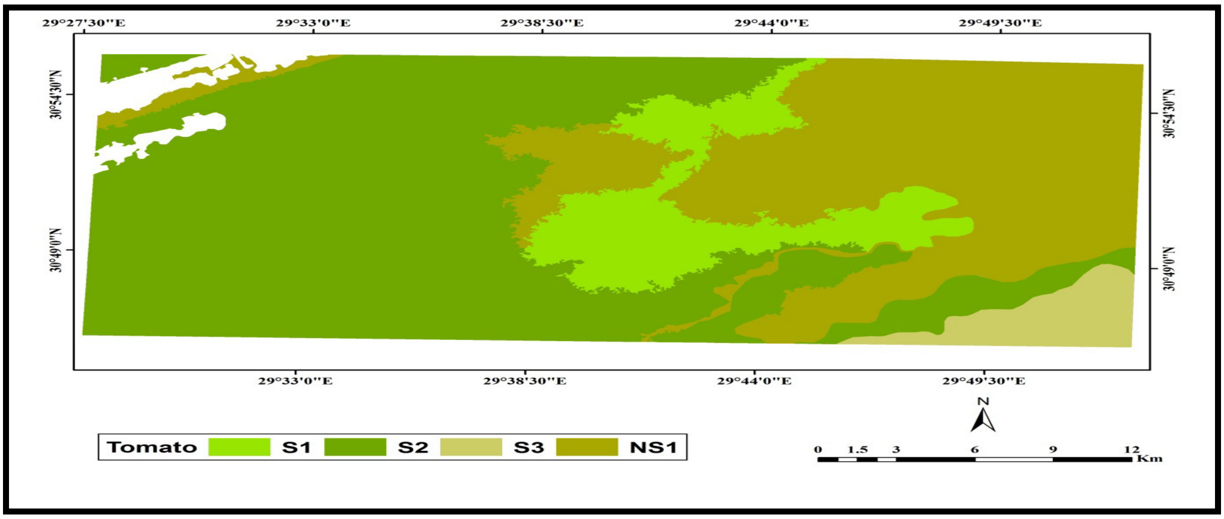

Fig. 6. Land suitability map for Tomato

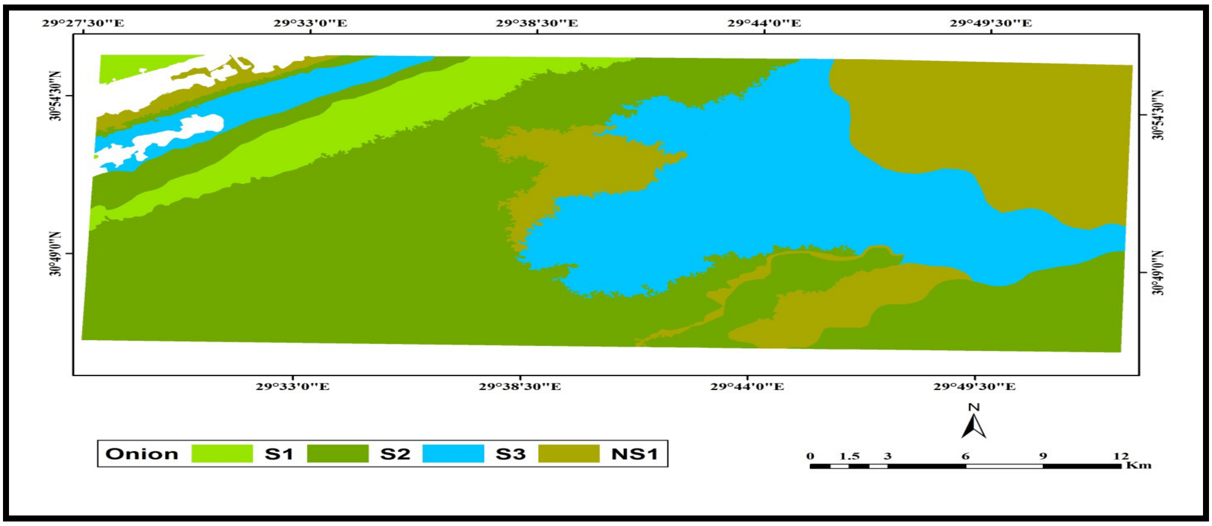

Fig. 7. Land suitability map for Onion

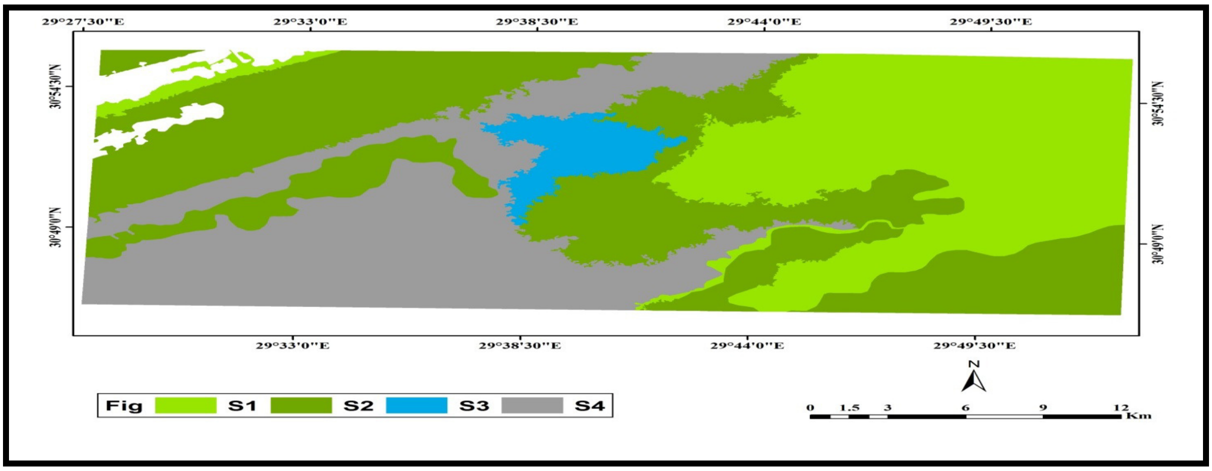

Fig. 8. Land suitability map for Fig

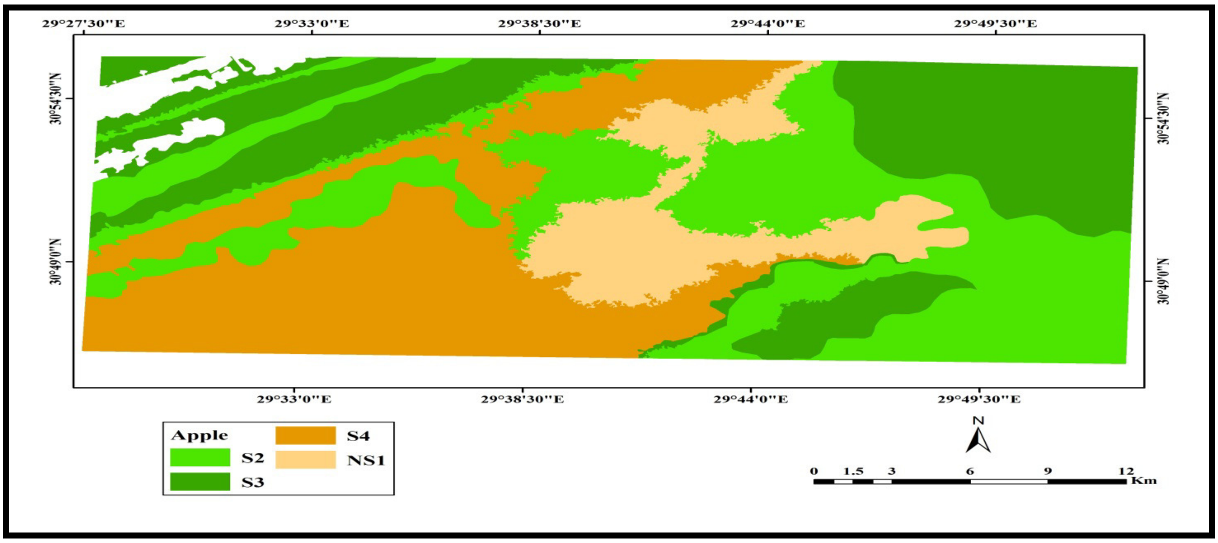

Fig. 9. Land suitability map for Apple

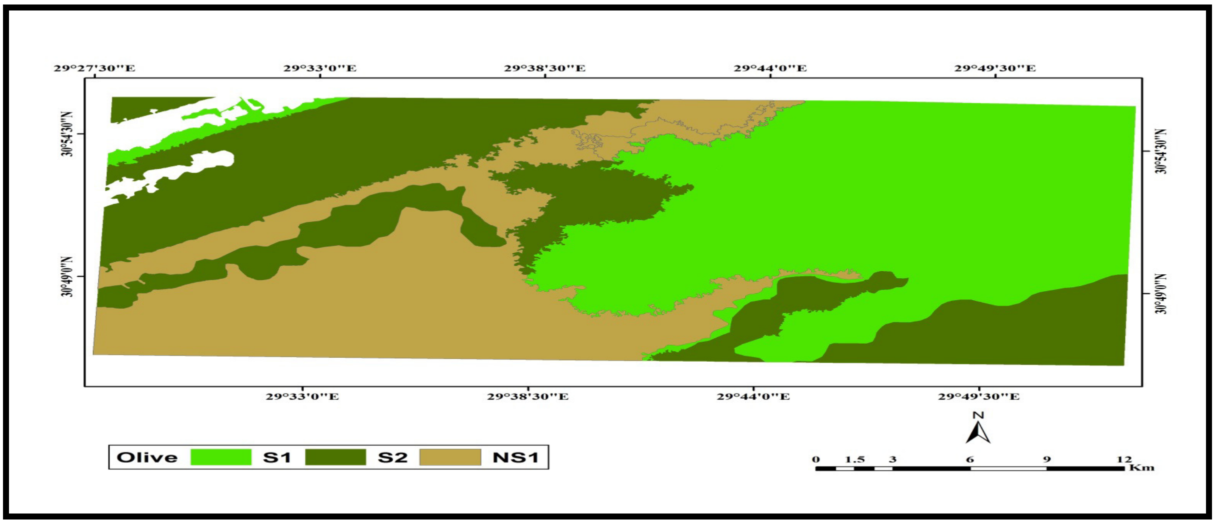

Fig. 10. Land suitability map for Olive

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نظـــم المعلـــومـــات الجغـــرافيـــة كأســـاس لتقييـــم بعض أراضـــي غـــرب الدلتـــا- مصـــــر

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أجرى تقييم الأراضي لبعض مناطق غرب دلتا النيل وذلك اعتمادًا على خصائص التربة المختلفة باستخدام نظم المعلومات الجغرافية، ووجد أن تقييم ملائمة الأراضي للاستخدام الزراعي الأمثل تعتبر واحده من أكثر الوسائل فعالية بالنسبة للتخطيط السليم لاستخدامات الأراضي الزراعية ومدى ملائمتها لزراعة المحاصيل المناسبة، والهدف من هذه الدراسة هو استخدام نظم المعلومات الجغرافية ونظام التقييم الإلكتروني لتقييم قدرة الأراضي ومدى ملائمتها لمختلف المحاصيل اعتمادا على خصائص التربة والظروف البيوفيزيائية، تم إجراء هذه الدراسة لبيان فائدة نظم المعومات الجغرافية إلى جانب بيانات التربة لتقييم مدى ملائمة المحاصيل للزراعة لتحقيق نظم الزراعة المستدامة في منطقة الدراسة، وكانت مدخلات نموذج التقييم عبارة عن خصائص التربة الطبيعية والكيميائية لتقييم قدرة الأرض الإنتاجية، ومدى ملائمة المحاصيل لظروف المنطقة، تم حفر ١٦ قطاع أرضى وتجميع عينات تربة منها، أظهرت نتائج الدراسة التباين في قدرة التربة بمنطقة الدراسة حيث صنفت المنطقة إلى أربع رتب لقدرة الأراضي على الزراعة والاستصلاح وهى (C1 أراضى جيدة، C2 أراضى متوسطة ، C3 أراضى ضعيفة ،C4 أراضى هامشيه) وكانت العوامل المحددة لقدرة الأرض الإنتاجية هى التضاريس وخصائص التربة ومخاطر التعرية والمناخ، وتشير النتائج الدراسة أن أراضي المنطقة تختلف من مكان لآخر حسب درجة ملائمة المحاصيل الحقلية التي تم اختيارها حيث لوحظ أن القمح يتراوح ما بين مرتفع الملائمة إلى غير ملائم في بعض الأجزاء في منطقة الدراسة ، وكانت الذرة مشابهه لمحصول القمح من حيث درجة الملائمة فى منطقة الدراسة، وأما بالنسبة لمحاصيل الخضر المختارة للزراعة في منطقة الدراسة فقد تراوحت درجة الملائمة للطماطم والبصل ما بين مرتفع الملائمة إلى غير ملائمة، وبالنسبة للفواكه فان التفاح قد تراوح ما بين ملائم إلى غير ملائم بينما التين والزيتون يجود في المنطقة بشكل مرتفع في أغلب مناطق الدراسة.

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